

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ :

A61M 25/10, A61F 2/06

A1

(11) International Publication Number:

WO 97/41916

(43) International Publication Date: 13 November 1997 (13.11.97)

(21) International Application Number: PCT/US97/07332

(22) International Filing Date: 2 May 1997 (02.05.97)

(30) Priority Data:

08/642,536

3 May 1996 (03.05.96)

US

(71) Applicant: EMED CORPORATION [US/US]; 651 Campus Drive, St. Paul, MN 55112 (US).

(72) Inventors: SHAPLAND, J., Edward; 4322 Rustic Place, Shoreview, MN 55126 (US). WALSH, Robert, G.; 6317 - 26th Street North, Oakdale, MN 55128 (US). FOWLER, Jan, Ellen; 7570 - 99th Street North, St. Paul, MN 55110 (US).

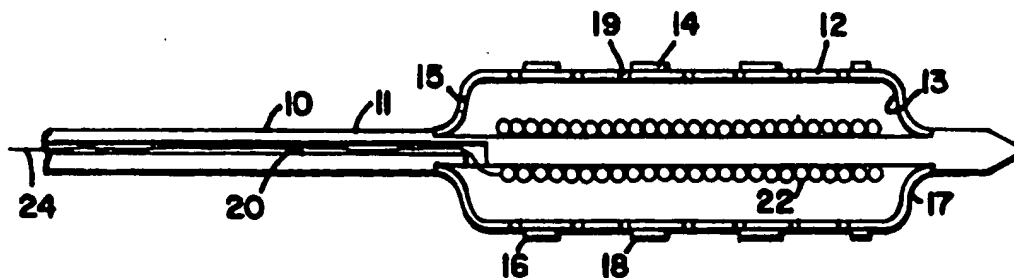
(74) Agent: BRUESS, Steven, C.; Merchant, Gould, Smith, Edell, Welter & Schmidt, P.A., 3100 Norwest Center, 90 South Seventh Street, Minneapolis, MN 55402-4131 (US).

(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published

*With international search report.**Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.*

(54) Title: COMBINED CORONARY STENT DEPLOYMENT AND LOCAL DELIVERY OF AN AGENT



(57) Abstract

The present invention is directed to the delivery of a stent to a vessel using a catheter having a balloon and a stent that is mounted on the balloon. The stent is positioned using a catheter, the stent is expanded using the catheter, and a therapeutic agent is delivered using the catheter.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakistan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LJ	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

COMBINED CORONARY STENT DEPLOYMENT AND LOCAL DELIVERY OF AN AGENT

TECHNICAL FIELD

5 The present invention relates to the treatment of cardiovascular ailments, and more particularly to combined coronary stent deployment and local delivery of an agent.

10 BACKGROUND

Angioplasty is commonly used to treat stenosis, which is a narrowing or stricture in a blood vessel. Stenosis is usually caused by a buildup of plaque or raised patches along the inner lining of an artery. Plaque can consist of fats, oils, decaying muscle cells, fibrous tissue, clumps of blood platelets, cholesterol, and calcium. Such a buildup is called a stenotic lesion and usually occurs in a coronary or peripheral artery.

During angioplasty, a balloon is inserted into the artery and positioned at the site of the stenotic lesion. The balloon is then inflated, which dilates the lumen in the artery and compresses and/or cracks the stenotic lesion. This action increases the size of the lumen formed by the vessel and improves blood flow. One problem with angioplasty is that there is a high rate of restenosis following the procedure, which is a renarrowing or reclosure of the vessel. In fact, about 30%-50% of patients receiving angioplasty experience restenosis within six months from the date that the procedure is performed.

Another complication from angioplasty is an abrupt reclosure of the vessel, which may be caused by a tear or rupture in the vessel wall. Such trauma can
35 cause a flap that falls into the lumen of the vessel and impedes blood flow.

One technique to prevent reclosure of the blood vessel due to maladies such as tears, ruptures,

and elastic recoil of the vessel wall after angioplasty is to place an intravascular stent at the site of the tear, rupture, or original stenosis. During this procedure, the angioplasty catheter is initially
5 inserted at the site of the stenotic lesion and expanded in order to expand the vessel and compress the lesion. The angioplasty balloon is removed and a second, balloon-type catheter is inserted and carries the stent to the site of the tear, rupture, or original stenotic
10 lesion.

The balloon of the second catheter is inflated to expand the stent against the vessel wall. Depending on the type of stent that is used, other types of catheters could be used in lieu of a balloon-type
15 catheter. The second catheter is removed after the stent is positioned.

In most cases, a third balloon-type catheter is introduced into the vessel and its balloon positioned within the stent. The balloon is then inflated to high
20 pressures in order to over expand the stent. Ensuring that the stent is fully expanded in this manner can reduce the rate of restenosis. Once in place, the stent acts as a semi-rigid structure that maintains the vessel in an open state.

A difficulty with this procedure is that it requires the insertion and removal of multiple catheters in order to perform the entire procedure, which increases the chances of complications and undue trauma to the patient. For example, there is an increased risk
30 of tears or damage to the vessel wall. There is further risk because using three separate catheters requires an increased amount of time to complete the surgical procedure. The risk of complications increases with the amount of time that a patient is subjected to a surgical
35 procedure. Cost is another problem. The cost of such a procedure is related to the amount of equipment and time that is required to perform the procedure.

Furthermore, stents do not prevent renarrowing due to maladies such as cell proliferation or the formation of a thrombus. Cell proliferation is the formation of scar tissue and can be caused from the presence of a foreign object within the body, a mismatch in the compliance between the stent and the vessel wall, or the healing of tears in the vessel wall. A thrombus is a blood clot that can be caused from turbulence in the blood flow that is induced by the stent.

Cell proliferation and the formation of a thrombus can be prevented with a therapeutic agent. Cell proliferation can be prevented with an agent such as an antiproliferative agent, and a thrombosis can be prevented with an agent such as an anticoagulant. Such drugs typically are delivered systematically and thus carried throughout the vascular system.

During systemic delivery, however, it is difficult to maintain the required therapeutic level of the agent in the patient's system. In order to maintain such a therapeutic level, a high dose of the agent must be administered to the patient. A problem is that antiproliferative agents are expensive, and agent that is delivered to areas of the body other than the treatment area is wasted. As a result, systemic delivery of the agent unnecessarily drives up the cost of the medical procedure.

Another problem is that systemic delivery can be harmful because the agent is exposed to healthy tissue as well as diseased tissue. As a result, systemic delivery can introduce unwanted side effects. For example, maintaining a high systemic level of an antiproliferative agent can cause unwanted cellular toxicity in healthy cells, and a high systemic level of an anticoagulant can cause internal bleeding or excessive bleeding at wounds such as the puncture wound required to permit catheter access.

Local delivery of a therapeutic agent at the treatment area is a possible alternative to systemic

delivery. The difficulty is that local delivery of the agent requires the introduction of yet another catheter that is specifically designed for drug delivery.

Introducing a fourth catheter is not desirable because
5 it will increase the risk of causing further trauma and side effects to the patient. It will also dramatically increase the expense of the procedure.

Therefore, there is a need for a single
apparatus and method that can position a stent, fully
10 expand the stent, and locally deliver an agent to the treatment area. There is a further need for an apparatus and method for performing angioplasty in addition to these functions. Such an apparatus and method would perform all of these functions with the
15 introduction of a single catheter.

SUMMARY

The present invention fills this need by providing an apparatus and method that delivers an agent, positions a stent, and expands a stent with a single catheter. The same catheter can also be used to perform angioplasty.

The apparatus comprises a catheter defining a lumen and a balloon in fluid communication with the lumen. The balloon defines pores sized about 1 μ or less. A stent is mounted on the balloon.

The present invention is also directed to an apparatus for delivering a stent to a treatment area that comprises a catheter defining a lumen. A balloon is in fluid communication with the lumen, and a stent is mounted on the balloon. The stent is formed with an electrically conductive material. A lead extends along the catheter. The lead has one end in electrical communication with the electrode and an opposite end configured to be connected to a power supply.

In yet another embodiment, a catheter defines a lumen. A balloon is in fluid communication with the lumen, and a stent is mounted on the balloon. The

balloon defines pores sized about 1 μ or less. The stent is formed from a biodegradable material or coated with a biodegradable material. The biodegradable material is configured to retain the agent and slowly release the agent.

The present invention is also directed to a method of delivering a stent to a vessel using a catheter having a balloon and a stent that extends around the balloon. The method comprises the steps of: positioning the balloon in the vessel so that the balloon and stent are proximate a treatment area; delivering a therapeutic agent to the treatment area while the balloon is proximate the treatment area; and inflating the balloon so that the stent expands against the vessel wall.

An alternative embodiment comprises the steps of: positioning the balloon and the stent in the vessel so that the balloon and stent are proximate a treatment area; delivering a therapeutic agent to the treatment area while the balloon is proximate the treatment area; and inflating the balloon thereby simultaneously expanding the stent against the vessel wall and performing angioplasty. Yet another alternative embodiment includes the steps of positioning the balloon and the stent in the vessel so that the balloon and stent are proximate a treatment area; and inflating the balloon with a therapeutic agent thereby simultaneously expanding the stent against the vessel wall, performing angioplasty, and delivering the therapeutic agent.

Still another embodiment of the present invention is directed to a method of performing angioplasty and delivering a stent to a vessel using a catheter having a balloon. The method comprises the steps of: performing angioplasty wherein the balloon is positioned in the vessel so that the balloon is proximate a treatment area, is inflated, and is removed from the vessel; and then deploying the stent wherein a stent is mounted on the balloon, the balloon is repositioned

proximate the treatment area, and is inflated so that the stent expands against the vessel wall.

DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a catheter of the present invention in which a stent is mounted on a microporous
5 balloon;

Figure 2 shows the catheter of Figure 1 and illustrates the microporous balloon in an inflated state and the stent in an expanded state;

Figure 3 shows the catheter of Figure 2 taken
10 along line 3-3 and illustrates an electrode positioned within a chamber defined by the microporous balloon;

Figure 4 illustrates an alternative embodiment of catheter shown in Figure 3 in which a surface of the microporous balloon is coated with an agent-retaining
15 material; and

Figure 5 illustrates another alternative embodiment of the catheter shown in Figure 3 in which the surface of the stent is coated with an agent-retaining material.

20

DETAILED DESCRIPTION

The present invention initially will be described in general terms. Various embodiments of the present invention, including a preferred embodiment, then
25 will be described in detail with reference to the drawings wherein like reference numerals represent like parts and assemblies throughout the several views. Reference to the described embodiments does not limit the scope of the invention, which is limited only by the
30 scope of the appended claims.

In general terms, the present invention relates to a catheter that can carry a stent, position the stent at a target area, fully expand the stent, and locally deliver an agent. In use, a caregiver introduces the
35 catheter into the patient's vessel and positions the stent at a treatment area. The caregiver can then expand

the stent and locally deliver an agent. The treatment area can include a stenotic lesion and surrounding tissue, a tear in the vessel, or a rupture in the vessel.

This apparatus and method has several
5 significant advantages. For example, insertion of the stent, expansion of the stent, and local delivery of the agent are performed with a single catheter. The caregiver does not have to introduce and withdraw multiple
10 catheters in order to perform this procedure. The amount of time required to complete the procedure is also reduced. Accordingly, the cost of the procedure, the amount of trauma, and the risk of complications are also reduced. Furthermore, local delivery of the agent can
15 permit maintenance of a therapeutic level of the agent while minimizing exposure of the agent to otherwise healthy tissue. The risk of causing side effects such as excessive bleeding is also reduced.

An agent can be any type of substance that is used for medical purposes and can be in a fluid form
20 such as a solution. Examples of agents include, but are not limited to, drugs, antiproliferative agents, anticoagulants, genetic material, biological agents, and radioactive substances such as isotopes. Radioactive substances are helpful because they kill cells in the
25 treatment area and prevent cell proliferation. An agent also can be a single agent or a combination of different agents. The term catheter as used in the present application is intended to broadly include, but is not limited to, any medical device designed for insertion
30 into a body passageway that can be used for both the deployment of a stent and delivery of an agent.

Referring now to Figure 1, a catheter 10 includes a catheter body 11 and a balloon 12 that forms a microporous membrane. The membrane can have pores sized
35 from about 10 Å to about 1 μ, and a pore density from about 10⁴ to about 10¹¹ pores per cm². Pores sized at or below about 150 Å are small enough to minimize the flow of fluid through the pores, but is still large enough to

permit the pores to be wetted and electric current to flow through the pores and carry the agent. A catheter having such a balloon is described in more detail in commonly assigned United States application serial number 5 08/376,765, filed on January 23, 1995 and entitled MICROPOROUS CATHETER, a Notice of Allowance for which has been issued, and the disclosure of which is hereby incorporated by reference.

A stent 14 is mounted on the balloon 12. The 10 length of the stent 14 is slightly less than the length of the balloon 12. In this configuration, the entire length of the stent 14 will expand upon inflation of the balloon 12. The stent is a tube 16 that defines a plurality of slits 18. The stent 14 can be formed from 15 biodegradable materials or metals. Examples of metals include, but are not limited to, stainless steel, nitinol, and tantalum. As an alternative to a rigid tube, the stent 14 can have other designs such as a coil spring, helical coil, tubular wire mesh, or any other 20 type of stent that can be expanded by the balloon 12.

Figure 2 illustrates the microporous balloon 12 and stent 14 in expanded states. When the stent 14 is in an expanded state, the slits 18 are widened, thereby providing the stent with an increased circumference. 25 Additionally, the stent 14 is semi-rigid in this state and will both comply with and maintain the expanded vessel wall in an open state.

Referring now to Figure 3, the balloon 12 defines a chamber 13 and has impermeable end caps 15 and 30 17. Impermeable end caps are described in more detail in commonly-assigned United States Patent 5,232,444, which is entitled Dilation Catheter, the disclosure of which is hereby incorporated by reference. Additionally, the catheter 10 includes an inflation lumen 20, a coil-wire 35 electrode 22 and a lead 24. The coil-wire electrode 22 is positioned in the chamber 13 and is wrapped around the catheter body 11.

The lead 24 is in electrical communication with the coil-wire electrode 22 and extends through the lumen 20 so that it can be connected to a power supply (not shown). A patch-type electrode (not shown) is configured to be placed against the patient's skin and is also connected to the power supply. Such power supplies and patch-type electrodes are well known in the art. Alternatively, one skilled in the art will realize that catheter 10 can have a bi-polar electrode arrangement. Bi-polar electrode arrangements are discussed in more detail in commonly-assigned United States Application serial number 08/291,394, filed on August 16, 1994 and entitled POLYMER MATRIX DRUG DELIVERY APPARATUS AND METHOD, the disclosure of which is hereby incorporated by reference.

In use, a caregiver will identify a treatment area where the stent 14 is to be located. The treatment area can be a site where a lesion is located, a site where angioplasty was performed, a site where a venous or synthetic vascular graft was inserted into a vessel, a site where a tear or rupture was caused in a vessel, or any other portion of a vessel that requires support. The treatment area is typically, but not necessarily, located in a coronary or peripheral artery.

The caregiver will introduce the catheter 10 into the vessel and position the stent 14 so that it is within the treatment area. The caregiver will then inject agent through the lumen 20 and into the chamber 13. The agent is pressurized from about 1 atm to about 10 atm, which wets the pores in the balloon 12, provides a path for electrical current to flow between the coil-wire electrode 22 and the patch-type electrode, and provides an initial expansion of the stent 14. The power source is then activated and the agent is iontophoretically transferred from the chamber 13 to tissue surrounding the balloon 12.

In order to minimize the risk of inducing arrhythmia during iontophoresis, one can use an

electrical signal having a particular waveform as disclosed in commonly-assigned United States Patent 5,499,971, which is entitled Iontophoresis Waveforms and the disclosure of which is hereby incorporated by
5 reference. The caregiver also can pace the heart during iontophoresis as disclosed in commonly-assigned United States patent application serial number 08/177,175, filed on January 4, 1994 and entitled SIMULTANEOUS CARDIAC PACING AND LOCAL DRUG DELIVERY, a Notice of Allowance for
10 which has issued and the disclosure of which is hereby incorporated by reference.

One skilled in the art will realize that phonophoresis also can be used to transport the agent from the balloon 12 to the target area. If phonophoresis
15 is used, the coil-wire electrode 22 is replaced with an ultrasonic transducer, and there is no patch-type electrode. Iontophoresis and phonophoresis are described in more detail in commonly-assigned United States Patent 5,286,254, which is entitled Microporous Membrane and the
20 disclosure of which is hereby incorporated by reference.

After the agent is delivered, the caregiver will increase the pressure of the agent within the chamber 13, which will cause the balloon 12 to further inflate and fully or over expand the stent 14. If the
25 caregiver wants greater control over the dose of agent that is delivered, he/she can withdraw the agent from the chamber 13 after delivery is completed and then inflate the balloon with a non-therapeutic substance such as sterile saline in order to expand the stent.

30 The stent is fully or over expanded when the stent 14 firmly presses against or becomes embedded in the vessel wall. In this state, the stent and vessel wall should conform with one another. One skilled in the art will realize that the level to which the pressure of
35 the agent is increased depends on the diameter of the vessel in which the stent 14 is placed and on how much the caregiver desires to expand the circumference of the stent 14. The larger the circumference that is desired,

the greater the pressure that must be applied to the agent.

In practice, the level to which the pressure of the agent is increased in order to fully or over expand the stent is typically between about 4 atm and about 20 atm. Such pressures ensure that all areas of the stent become expanded and firmly press against the vessel wall. After the stent 14 is expanded, the balloon 12 is deflated and the catheter 10 is withdrawn from the patient.

One skilled in the art will realize that there are other sequences of operation in which the steps described above can be performed. For example, the caregiver can continue to transport the agent while the stent is being expanded. The caregiver can also continue to transport agent after the sent is expanded. In another possible sequence of steps, the stent could be expanded prior to delivery of the agent.

As an alternative to the method described above, the stent 14 can be heated or cooled in order to cause it to expand if nitinol metal is used to form the stent 14. Nitinol metal has a memory. When nitinol metal is heated or cooled from an original temperature to a selected memory temperature and reshaped from a first shape to a second shape, its memory is set so that the metal will return to the first shape when it is reheated or recooled to the selected memory temperature. In use, the nitinol metal is heated or cooled to the selected memory temperature in order to expand the stent 14. The stent 14 could be warmed by heating or cooling the agent that is injected into the balloon 12 or by injecting a heated or cooled fluid into the balloon 12 either before or after the agent is injected into the balloon 12.

The selected memory temperature can be set at body temperature in which case the stent 14 will maintain its expanded shape. If the memory temperature is set at body temperature, the caregiver can rely on body heat generated by the patient to expand the stent. The

caregiver could also artificially heat the metal to body temperature.

Alternatively, a nitinol stent that is already deployed in a vessel can be repositioned or removed by positioning a catheter balloon in the stent and then either heating or cooling the stent to its original temperature so that it shrinks and becomes remounted on the balloon. If the stent is being repositioned, the catheter can be moved to the new location and the stent can then be allowed to cool or warm to the first memory temperature and reexpand. If the stent is being removed, the catheter simply can be removed from the patients body.

As another alternative method, it is also possible to use the catheter 10 to perform angioplasty. If the catheter 10 is used to perform angioplasty, the caregiver can simultaneously perform angioplasty, deliver the agent, and expand the stent. Simultaneous angioplasty and delivery of the agent is discussed in more detail in commonly-assigned United States Patent 5,498,238, which is entitled Simultaneous Angioplasty/Drug Delivery, the disclosure of which is hereby incorporated by reference. The caregiver could also deliver the agent either before or after angioplasty is performed and the stent 14 is expanded.

The caregiver could also use the catheter 10 to perform angioplasty and deliver an agent, withdraw the catheter 10, mount the stent 14 on the catheter 10, reintroduce the catheter to deploy the stent 14, and deliver additional agent. This alternative method is advantageous because the caregiver can use the microporous balloon 12 to simultaneously deliver a first drug such as an antiproliferative agent during angioplasty and to simultaneously deliver a second agent such as an anticoagulant during stent deployment. There is additional advantage because only a single catheter 10 is needed to perform angioplasty, deliver the agents, and deploy the stent 14. As a result, there is a cost

savings because less medical equipment is needed.

Furthermore, the medical procedure can be performed much more efficiently because the amount of equipment that the caregiver must handle is reduced.

5 Pressure can also be used as the primary transport mechanism for delivering the agent. If pressure is the primary transport mechanism, one skilled in the art will recognize that catheter 10 does not need to include the electrode 22 and the lead 24. During use, 10 the caregiver pressurizes the agent within the balloon 12 to a first predetermined level, which will cause the agent to flow through pores defined in the balloon. The first predetermined level is between about 1 atm and about 10 atm. After the agent is delivered, the 15 caregiver increases the pressure of the agent to a second predetermined level, which will cause the balloon 12 to expand and thus cause the stent 14 to expand. The second predetermined level is between about 4 atm and about 20 atm.

20 If pressure is a transport mechanism, the pore size and density can be set so that: (1) only a minimal amount of agent will flow through the pores at the first predetermined pressure level; and (2) the prescribed dose of agent will wet and flow through the pores at the 25 second predetermined level. Controlling the pore size in this manner is described in more detail in commonly-assigned United States Patent 5,458,568, which is entitled Selectively Permeable Membrane for Drug Delivery Catheter, the disclosure of which is hereby incorporated 30 by reference. Alternatively, if the prescribed dose of agent is delivered at the first predetermined level, the agent is withdrawn from the balloon 12 and a second, non-therapeutic fluid is injected into the balloon 12 to expand the stent 14. Pressure also can be used in 35 conjunction with iontophoretic or phonophoretic delivery.

Referring to Figure 4, an alternative embodiment includes an agent-retaining coating 26 on the outer surface of the balloon, which can be impregnated

with the agent. The coating can be any suitable material that can retain the agent such as a polymer matrix or an open-cell foam. The agent-retaining coating 26 can be formed from either a compressible or a non-compressible material. However, a non-compressible material is advantageous because non-compressible material will minimize any loss of the agent as the catheter 10 is maneuvered through the vessel and prematurely becomes compressed against the vessel wall. Polymer matrixes as an agent-retaining reservoir is described in more detail in commonly-assigned United States patent application serial number 08/291,394, the disclosure of which was incorporated by reference above.

In use, the balloon 12 is dipped into a supply of agent in order to load the agent-retaining coating 26 before the catheter 10 is introduced into the vessel. The caregiver can then follow the treatment steps as described above. However, the balloon 12 can be inflated with any type of fluid, such as sterile saline, that will provide a conductive path between the coil-wire electrode 22 and the agent-retaining coating 26. The inflation fluid can also contain additional agent or a different type of agent.

Alternatively, the agent-retaining material 26 can be loaded after the balloon 12 and stent 14 are positioned at the treatment area. After the balloon 12 is positioned, the agent is injected into the chamber 13 via the lumen 20. The agent is then slightly pressurized between about 2 atm to about 3 atm, which will cause some agent to flow through the pores and saturate the agent-retaining material. If this alternative method is used, the pores have a size greater than about 150 Å. Additionally, the agent-retaining material can be swellable and compressible.

In an alternative embodiment to the configuration shown in Figure 4, a metallic coating (not shown) can be used in place of the coil-wire electrode 22. The metallic coating can be positioned between the

outer surface of the balloon 12 and the agent-retaining coating 26. In this configuration, the balloon 12 can be formed from an impermeable material. Alternatively, the metallic coating can be applied to the inner surface of the balloon 12, in which case the balloon 12 is porous in order to provide electrical communication between the electrode and the agent-retaining coating 26. In yet another alternative embodiment, no electrode is present. In this alternative embodiment, the balloon 12 can be impermeable, and pressure is the primary mechanism for delivering agent from the agent-retaining coating 26. In this alternative embodiment, the agent-retaining coating 26 is preloaded before the catheter 10 is introduced into the vessel.

Referring to Figure 5, another alternative embodiment of the present invention includes an agent-retaining coating 28 applied to the outer surface of the stent 14. The coating can be formed from either a biodegradable material or a non-biodegradable material. The coating 28 is designed to reduce premature diffusion of the agent. One technique for reducing premature diffusion of the agent is to entrap the agent within the coating 28. Release or diffusion of the agent then can be limited to allowing the coating 28 to degrade or to phoretically transporting the agent using a mechanism such as iontophoresis or phonophoresis. Additionally, the coating 28 can be a polymer matrix. Nevertheless, one skilled in the art will realize that the coating can have a number of other physical structures.

Additionally, a strip 30 extends along the length of the balloon 12. The strip 30 is formed from an electrically conductive material and provides electrical communication between the lead 24 and the stent 14. The strip 30 can separate from the stent 14 upon deflation of the balloon 12. In this configuration, the catheter can be removed from the patient and the stent 14 can be left behind, i.e., positioned in the vessel. In lieu of

having the strip 30, the balloon 12 can be coated with a metallic material.

The stent 14 also is formed from an electrically conductive material and the lead 24 is operably connected to the strip 30. The lead 24 extends down through the catheter body 11 and extends through the lumen 20. In this configuration, the stent 14 acts as an electrode.

The embodiment shown in Figure 5 is used in a manner that is substantially similar to the steps described above. During iontophoresis, an electrical current passes between the stent 14 and the patch-type electrode that is affixed to the patient's body. The electrical current will transport the agent from the agent-retaining coating 28 to tissue surrounding the stent 14.

Additionally, the balloon 12 can be inflated with an agent, which would permit simultaneous transport of an agent from the chamber 13 of the balloon 12 and from the agent-retaining coating 28. The agent used to inflate the balloon 12 could be the same agent that is included in the agent-retaining coating 28 or could be a different agent than the agent included in the agent-retaining coating 28. Alternatively, the balloon 12 can be formed from an impermeable material and can be inflated with any suitable fluid.

Alternatively, the agent-retaining coating 28 can be formed from a biodegradable material. In this embodiment, the agent-retaining coating 28 will gradually degrade after the stent 14 is positioned in the vessel and the catheter 10 is removed. This embodiment is advantageous because a therapeutic level of the agent can be maintained at the treatment area for an extended period of time after the catheter is removed. This embodiment might be used for the sustained release of an anticoagulant such as an antithrombotic agent in order to prevent formation of a thrombus.

If the agent-retaining coating 28 is biodegradable, iontophoresis or phonophoresis could still be used to transport the agent. Alternatively, the agent can be delivered by simply placing the stent 14 in the vessel. In this alternative delivery, the catheter 10 does not need to include an active transport mechanism such as an electrode or an ultrasonic transducer. Furthermore, the balloon 12 can be formed from an impermeable material.

In yet another alternative, if the agent-retaining coating 28 is formed from biodegradable material and the agent included in the coating 28 has a neutral charge, there could be both immediate delivery of an agent and sustained delivery of an agent. Immediate delivery could occur by delivering the agent that is injected into the chamber 13 by use of iontophoresis, phonophoresis, or pressure. If iontophoresis is used, the strip 30 can be replaced with the coil-wire electrode 22. If phonophoresis is used, the strip 30 is replaced with an ultrasonic transducer. Sustained release of the agent could occur by allowing the agent-retaining coating 28 to degrade thereby releasing the agent that is included within the coating 28. This alternative delivery is advantageous when delivering both an anticoagulant and an agent such as an antiproliferative agent or radioactive isotope.

While the invention has been described in conjunction with a specific embodiments thereof, it is evident that other alternatives, modifications, and variations can be made in view of the foregoing description. Accordingly, the invention is not limited to these embodiments or the use of elements having specific configurations and shapes as presented herein. Rather, the scope and spirit of the present invention is dictated by the following claims.

THE CLAIMED INVENTION IS:

1. A method of delivering a stent to a vessel using a catheter having a balloon and a stent that is mounted on the balloon, the method comprising the steps of:
 - 5 positioning the balloon and the stent in the vessel so that the balloon and stent are proximate a treatment area;
 - delivering a therapeutic agent to the treatment area while the balloon is proximate the treatment
 - 10 area; and
 - inflating the balloon so that the stent expands against the vessel wall.
2. The method of claim 1 further comprising the
 - 15 following additional steps, which are performed prior to the step of positioning the balloon and the stent:
 - positioning the balloon in the vessel;
 - inflating the balloon thereby performing angioplasty;
 - 20 withdrawing the balloon from the vessel; and
 - mounting the stent on the balloon.
3. The method of claim 1 wherein the step of inflating the balloon includes the step of performing angioplasty
 - 25 at the treatment area.
4. The method of claim 1 wherein the step of delivering the therapeutic agent includes the step of iontophoretically delivering the therapeutic agent.
 - 30
5. The method of claim 1 wherein the step of delivering the therapeutic agent includes the step of phonophoretically delivering the therapeutic agent.
- 35 6. The method of claim 1 wherein the step of delivering the therapeutic agent includes the step of delivering the therapeutic agent from a coating applied to the stent.

7. The method of claim 1 wherein the balloon defines a chamber and is formed from a porous material, the step of delivering the therapeutic agent includes the steps of:
supplying the therapeutic agent to the chamber; and
5 delivering the therapeutic agent from the chamber to the treatment area.
8. The method of claim 7 wherein:
the step of delivering the therapeutic agent
10 includes the step of pressurizing the fluid in the chamber to a first predetermined pressure; and
the step of inflating the balloon so that the stent expands includes the step of pressurizing the
15 fluid in the chamber to a second predetermined pressure, the second predetermined pressure being greater than the first predetermined pressure.
- 20 9. The method of claim 7 wherein the balloon defines a chamber and is formed from a porous material, the step of delivering the therapeutic agent and inflating the balloon being performed simultaneously.
- 25 10. A method of delivering a stent to a vessel using a catheter having a balloon and a stent that is mounted on the balloon, the method comprising the steps of:
positioning the balloon and the stent in the vessel
so that the balloon and stent are proximate a
30 treatment area;
delivering a therapeutic agent to the treatment area while the balloon is proximate the treatment area; and
inflating the balloon thereby simultaneously
35 expanding the stent against the vessel wall and performing angioplasty.

11. A method of delivering a stent to a vessel using a catheter having a balloon and a stent that is mounted on the balloon, the method comprising the steps of:

5 positioning the balloon and the stent in the vessel
 so that the balloon and stent are proximate a
 treatment area; and
 inflating the balloon with a therapeutic agent
 thereby simultaneously expanding the stent
 against the vessel wall, performing
10 angioplasty, and delivering the therapeutic
 agent.

12. A method of performing angioplasty and delivering a
stent to a vessel using a catheter having a balloon, the
15 method comprising the steps of:

 performing angioplasty wherein the balloon is
 positioned in the vessel so that the balloon is
 proximate a treatment area, is inflated, and is
 removed from the vessel; and then
20 deploying stent wherein a stent is mounted on the
 balloon, the balloon is repositioned proximate
 the treatment area, and is inflated so that the
 stent expands against the vessel wall.

25 13. The method of claim 12 further comprising the step
of delivering an agent during the first step of
performing angioplasty.

14. The method of claim 13 further comprising the step
30 of delivering additional agent during the second step of
deploying the stent.

15. The method of claim 14 wherein different agents are
delivered during the step of delivering an agent and the
35 step of delivering additional agent.

16. An apparatus for delivering a stent to a treatment
area, the apparatus comprising:

- a catheter defining a lumen;
a balloon in fluid communication with the lumen,
wherein the balloon defines pores sized about 1
 μ or less; and
5 a stent mounted on the balloon.

17. The apparatus of claim 16 wherein the stent is
coated with an agent-retaining material, the agent-
retaining material being configured to retain an agent.
10

18. The apparatus of claim 17 wherein the agent
retaining material is a polymer matrix.

19. The apparatus of claim 17 wherein the agent
15 retaining material is biodegradable.

20. The apparatus of claim 16 wherein the stent is
formed from a biodegradable material.

20 21. The apparatus of claim 20 wherein the biodegradable
material includes an agent.

22. The apparatus of claim 16 wherein an agent-retaining
material is positioned between the balloon and the stent,
25 the agent-retaining material being configured to retain
an agent.

23. The apparatus of claim 22 wherein the agent-
retaining material is a polymer matrix.
30

24. The apparatus of claim 16 further comprising first
and second electrodes, the first electrode being operably
connected to the balloon, the first and second electrodes
configured to be electrically connected to a power
35 supply.

25. The apparatus of claim 24 wherein the second electrode is operably connected to the catheter thereby forming a bipolar electrode configuration.
- 5 26. The apparatus of claim 24 wherein the second electrode is configured to be placed against a patient's skin.
- 10 27. The apparatus of claim 24 wherein the balloon defines a chamber and the first electrode is positioned in the chamber.
- 15 28. The apparatus of claim 24 wherein the balloon has an outer surface and the first electrode is positioned against the outer surface.
- 20 29. The apparatus of claim 28 wherein the first electrode is a metallic coating applied to the outer surface.
- 25 30. The apparatus of claim 18 wherein the stent is formed from an electrically conductive material and forms the first electrode, the apparatus further comprising a lead, the lead being configured to provide electrical communication between the power supply and the stent.
- 30 31. The apparatus of claim 30 further comprising an electrically conductive material, the electrically conductive material being positioned between the balloon and the stent and providing electrical communication between the lead and the stent.
- 35 32. The apparatus of claim 16 further comprising an ultrasonic transducer, the ultrasonic transducer being operably connected to the balloon and configured to be electrically connected to a power supply.

33. The apparatus of claim 16 wherein the balloon defines a chamber and the ultrasonic transducer is positioned in the chamber.

5 34. An apparatus for delivering a stent to a treatment area, the apparatus comprising:

a catheter defining a lumen;

a balloon in fluid communication with the lumen;

10 a stent mounted on the balloon, the stent being formed with an electrically conductive

material; and

a lead extending along the catheter, the lead having

one end in electrical communication with the

stent and an opposite end configured to be

15 connected to a power supply.

35. An apparatus for delivering a stent to a treatment area, the apparatus comprising:

a catheter defining a lumen;

20 a balloon in fluid communication with the lumen, the balloon defining pores sized about 1 μ or less; and

a stent mounted on the balloon, the stent being

coated with a biodegradable material, the

25 biodegradable material being configured to retain the agent and release the agent as it degrades.

FIG.1

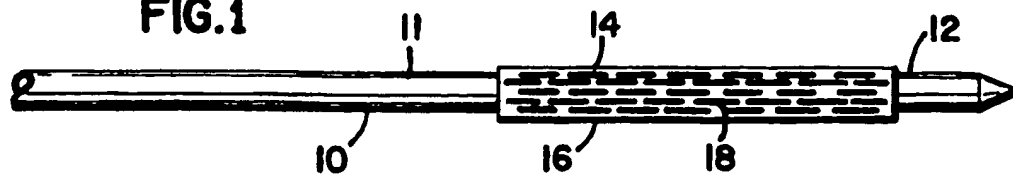


FIG. 2

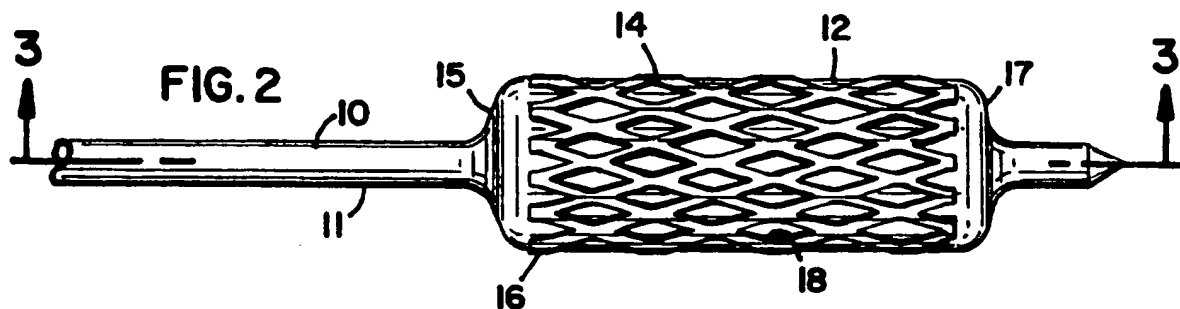


FIG. 3

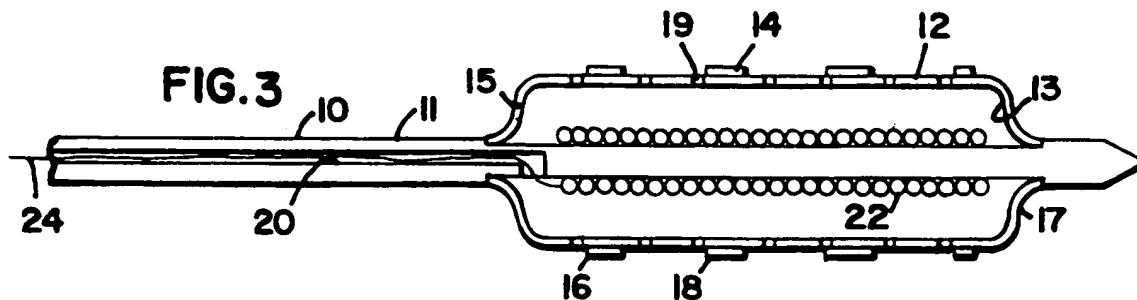


FIG. 5

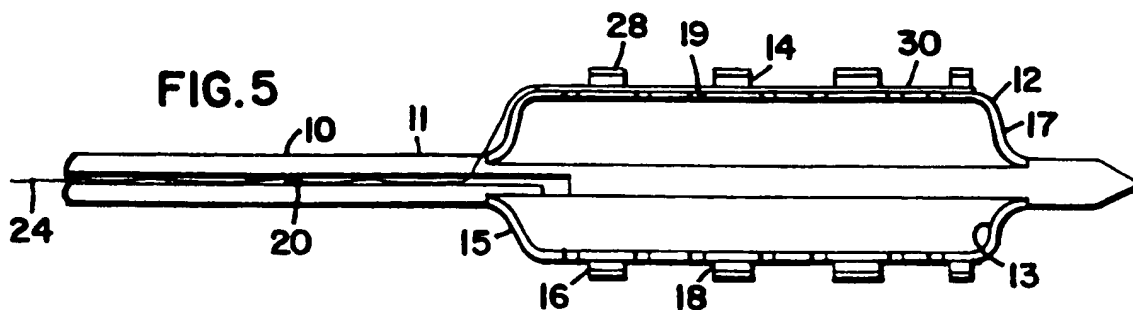
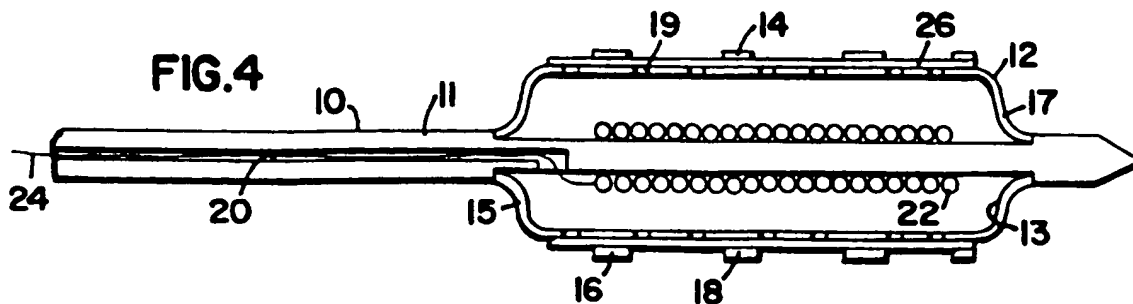


FIG. 4



INTERNATIONAL SEARCH REPORT

Internatio. .pplication No

PCT/US 97/07332

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61M25/10 A61F2/06

According to International Patent Classification (IPC) or to both national classification and IPC.

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61M A61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 364 787 A (EXPANDABLE GRAFTS PARTNERSHIP) 25 April 1990	16,24-27
A	see abstract; figures ---	34,35
Y	US 5 236 413 A (FEIRING) 17 August 1993 see the whole document ---	16,24-27
A	WO 96 11720 A (IGAKI IRYO SEKKEI) 25 April 1996 ---	
A	US 5 213 576 A (ABIUSO ET AL) 25 May 1993 ---	
A	US 5 364 356 A (HÖFLING) 15 November 1994 ---	
A	US 5 254 089 A (WANG) 19 October 1993 ---	
A	US 5 318 531 A (LEONE) 7 June 1994 ---	
	-/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *&* document member of the same patent family

Date of the actual completion of the international search

17 September 1997

Date of mailing of the international search report

30.09.97

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+ 31-70) 340-3016

Authorized officer

Smith, C

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 97/07332

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>WO 93 25265 A (MALLINCKRODT MEDICAL, INC.) 23 December 1993</p> <p>-----</p>	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 97/07332

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 1-15
because they relate to subject matter not required to be searched by this Authority, namely:
RULE 39.1 (iv) PCT - Method for TREATMENT OF THE HUMAN OR ANIMAL BODY
BY SURGERY
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such
an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all
searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment
of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report
covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is
restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 97/07332

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 364787 A	25-04-90	AU 623438 B	14-05-92
		AU 4248589 A	12-04-90
		CA 1322628 A	05-10-93
		JP 2174859 A	06-07-90
		US 5195984 A	23-03-93

US 5236413 A	17-08-93	AU 642020 B	07-10-93
		AU 7901091 A	27-11-91
		CA 2081666 A	08-11-91
		EP 0527920 A	24-02-93
		WO 9116945 A	14-11-91
		US 5425703 A	20-06-95
		US 5549603 A	27-08-96

WO 9611720 A	25-04-96	AU 3674295 A	06-05-96
		EP 0761251 A	12-03-97

US 5213576 A	25-05-93	US 5405472 A	11-04-95
		US 5318531 A	07-06-94

US 5364356 A	15-11-94	DE 4324218 A	26-01-95
		AT 148352 T	15-02-97
		AU 5177593 A	20-02-95
		CA 2167573 A	02-02-95
		CN 1097633 A	25-01-95
		CZ 9600116 A	17-04-96
		DE 59305366 D	13-03-97
		WO 9503081 A	02-02-95
		EP 0710132 A	08-05-96
		ES 2096951 T	16-03-97
		FI 960219 A	17-01-96
		HU 73327 A	29-07-96
		JP 9500303 T	14-01-97
		NO 960201 A	17-01-96
		PL 312612 A	29-04-96
		SK 8696 A	08-05-96

US 5254089 A	19-10-93	CA 2133567 A	14-10-93
		EP 0633796 A	18-01-95
		JP 7507698 T	31-08-95

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 97/07332

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5254089 A		US 5389314 A	14-02-95
		WO 9319800 A	14-10-93

US 5318531 A	07-06-94	US 5213576 A	25-05-93
		US 5405472 A	11-04-95

WO 9325265 A	23-12-93	AU 4408193 A	04-01-94
		CA 2136839 A	23-12-93
		EP 0646031 A	05-04-95
		JP 7507704 T	31-08-95

THIS PAGE BLANK (USPTO)